

World Wide Web Platform-independent Access to Biomedical Text/Image Databases

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ABSTRACT

The biomedical digital library of the future is expected to provide access to stores of biomedical database information containing text and images. Developing efficient methods for accessing such databases is a research effort at the Lister Hill National Center for Biomedical Communications of the National Library of Medicine.

In this paper we examine issues in providing access to databases across the Web and describe a tool we have developed: the Web-based Medical Information Retrieval System (WebMIRS). We address a number of critical issues, including preservation of data integrity, efficient database design, access to documentation, quality of query and results interfaces, capability to export results to other software, and exploitation of multimedia data.

WebMIRS is implemented as a Java applet that allows database access to text and to associated image data, without requiring any user software beyond a standard Web browser. The applet implementation allows WebMIRS to run on any hardware platform (such as PCs, the Macintosh, or Unix machines) which supports a Java-enabled Web browser, such as Netscape or Internet Explorer. WebMIRS is being tested on text/x-ray image databases created from the National Health and Nutrition Examination Surveys (NHANES) data collected by the National Center for Health Statistics.

Keywords: World Wide Web, biomedical, informatics, Internet, database, spine, digital image, morphometry, x-ray image, image query by content, NHANES, NLM, NCHS, NIAMS

1. INTRODUCTION

We approach the problem of providing wide-area network access to multimedia biomedical databases from the engineering perspective of exploiting technology for making important health-related data sets readily available to researchers and to the general public on a national scale. The principal content of the research databases we have created comes from national health surveys conducted by the National Center for Health Statistics (NCHS), although our work is not limited to this data only. There have been a series of these surveys. The purpose of the surveys may be understood by this excerpt from NCHS documentation¹ for the third survey (NHANES III):

The goals of the NHANES III are in many respects similar to those of earlier NHANES:

1. *to estimate the national prevalence of selected diseases and risk factors*
2. *to estimate national population reference distributions of selected health parameters*
3. *to document and investigate reasons for secular trends in selected diseases and risk factors*
4. *to contribute to an understanding of disease etiology*
5. *to investigate the natural history of selected diseases*

Previous NHANES have shared the first three of these goals, but the last two are new for the NHANES III. The previous NHANES were designed as descriptive surveys and sometimes used for analytic purposes. The NHANES III has been designed to be both a descriptive survey and an analytic study as well, and the last two goals in the list reflect this new analytic intent of the study design. The NHANES III was also intended to be a longitudinal study enhancing the analytic goals of the study.

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In the past, the NCHS survey data has been available only by means of data tapes on mainframe computers; the most recent NCHS survey data release, NHANES III, has been made available also on CD-ROM²; to date, none of the data is available using Internet access. Furthermore, the x-ray image data in the NCHS surveys has been collected and archived as single-copy films, and access has been very limited by the need to check out and physically handle these films. Precision scanning technology, coupled with modern storage, display, and communications technology, now makes the wide distribution of this data in digital form a realistic goal. In collaboration with NCHS and the National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS), we have created a digital archive of the 17,000 cervical and lumbar spine x-rays collected in the second survey (NHANES II) and are now developing a prototype system to enable World Wide Web access to databases created from the NHANES II and III surveys, including the digitized NHANES II x-ray images, as well as the text information from both surveys.

Our goals are to research the design of and to prototype a system (1) to make important health databases available to a wider group of users, with more ease of use, and fewer hardware and software requirements than has been possible up to the current time; (2) to deliver not just raw data, but to create a *biomedical informatics system*: to include all the explanatory and descriptive documentation, links to other resources, built-in analysis features, and interfaces to other analysis tools, so that it is a robust research and biomedical informatics tool, as well as a data access tool for the general user; and (3) to begin the direct exploitation of the informational content of the image data. We call this prototype system the *Web-based Medical Information Retrieval System (WebMIRS)*.

Access to data collections containing both text and images has been a particularly acute problem in the biomedical community, where facilitated data availability is expected to have significant impact on health research and possibly even clinical care. Many image collections are available only in film form, requiring sequential access by users, and necessitating the handling of bulky media subject to damage and loss. Further, such collections may not be part of an integrated system, which allows a user to view descriptive text information, and to easily associate it with the film image. A concrete example of such a collection is NHANES II³, conducted in the years 1976-1980. A search of the NLM MEDLINE bibliographic database conducted in 1994 yielded over 800 citations corresponding to studies using the *text* data collected in this survey, showing the wide interest in the research community in the data. In contrast, the x-ray films collected were only available by temporary loan from NCHS, and were accessed only nine times.

The initial databases being used in our system are derived from the NHANES data referenced above. The NHANES II survey was conducted on a national sample of 27,801 persons, and collected information describing the demographic, socioeconomic, and medical characteristics of the participants, including results obtained by interview, testing by medical personnel, and direct examination by physician. Image data collected included film x-rays of the cervical and lumbar spine. The 17,000 NHANES II films have been digitized and reside in magneto-optical storage at NLM. NHANES III was conducted during the years 1988-1994 and included interviews with 33,994 participants; 30,818 persons were examined in the NCHS Mobile Examination Centers, and an additional 493 were examined at home. Data collected were generally similar to the previous NHANES: a listing of the data collected by health status component illustrates the many investigative areas supported by this rich data set. These components are cardiovascular disease, respiratory disease, diabetes mellitus, diabetic retinopathy and vision, thyroid function, reproductive health, kidney disease, gallstone disease, arthritis and related musculoskeletal conditions, osteoporosis, functional health status in the elderly, allergy, immunization and infectious diseases, hearing, lead exposure, mental health and neurobehavioral function, and oral health. Image data collected in NHANES III included x-ray film of the hands and knees, bone densitometry in the hip region, gallbladder ultrasonography, and retinal fundus photography. In addition, graphical electrocardiogram data was acquired. A study⁴ was conducted by NCHS and NLM to determine acceptable resolution for digitizing the x-ray films of the hand, and we expect that these images, once digitized, will also be available to NLM for distribution in our prototype systems.

Our systems development research will initially use two databases derived from the NHANES data collections: (a) our NHANES II database containing the digitized spine images of the cervical and lumbar regions, plus a subset of the descriptive text data which will include demographic information, body measurements, and the physician's examination of the back; (b) our NHANES III database containing the digitized hand and knee images (when available), plus a subset of the text data which will include demographics, body measurements, physician's examination of the hands and knees, and laboratory measurements. Since the NHANES III data have only been publicly available since July 1997, these are expected to be in more demand. We expect to increase the quantity of included data as interested user communities become aware of the potential of our system for providing access. Our research goal is to evaluate technology for the efficient dissemination of multimedia biomedical data to the research and educational communities, and to the general public.

In this paper we describe our system development work in providing access to such mixed text/image databases as represented by NHANES.

2. DESIGN ISSUES

We have addressed basic architectural issues for the system, such as the decision to implement the system as a Java applet as opposed to an HTML/CGI application, elsewhere⁵. In this section we discuss additional design issues.

Preservation of data integrity. Since the databases used by WebMIRS are a redistribution of data from the original sources by means of new data structures, the question of whether the data items have been accurately preserved must be addressed. The original data source is a set of “flat”, unstructured ASCII files distributed by NCHS. For the WebMIRS system we have extracted data from these files and put the data into tables with our relational data base system. Location and size of data fields within the ASCII files is provided in NCHS documentation. Since manual entry of field size and location data is not only tedious but prone to error, we have automated the data extraction by writing *perl* scripts to first take field size and location out of the documentation, then to use this information to do the actual data extraction from the original data files. For NHANES III we were aided by the fact that the documentation was available in electronic form; for NHANES II, the documentation exists only in paper form. This requires us to carry out an additional preliminary step of converting the NHANES II documentation to electronic form by scanning and optical character recognition, augmented by manual comparison of the resulting electronic document with the original.

Efficient database design. One feature of the WebMIRS system is that some components of the GUI are not shown until query time and are, in fact, dependent on the particular query constructed by the user. For example, if a user wants to query on age, after the user selects *age* from the GUI, WebMIRS presents a list box containing a choice of relational operators (e.g., =, >, <), plus a text entry box for entering a numerical value (e.g., 50). These same controls would not be appropriate for creating a query clause such as *sex = female*, however; for this query, once *sex* is selected, WebMIRS only needs to present a list box containing the options *male* and *female*. This dynamic GUI processing, driven by the nature of the query, is handled in a natural way by maintaining within the database itself information about which controls should appear on the screen as a result of the particular query being formulated. Hence, the database knows that *age selection* is related to the GUI list box control which contains the appropriate *relational operators*; it knows that *relational operator selection* is related to the GUI text entry box to receive the *user-entered age value*; and it knows the contents which should be displayed in any list box that should be displayed. In the original implementation of the WebMIRS system we stored this GUI information in the same tables as the data values themselves and used character data displayed on the GUI as search keys for the data values. This table construction method, though simple, resulted in very inefficient query performance: to search for a particular data value, the DBMS had to load rows containing not only data values, but also character data which was presented on the GUI; in addition, in order to find data values matching the query criteria, the DBMS had to do string comparisons on as many as five character fields to identify the data value. For the current WebMIRS, we are implementing tables where the GUI information is stored completely separately from the data values. When the user creates a query, these GUI tables are used to get a query index, uniquely identifying the query. This query index is used to find the data values for that query. Lesson learned: control of a query driven dynamic GUI by use of GUI information contained in the database itself works well, but the GUI information should be decoupled from the data values with respect to storage and data value searching in the database.

Access to documentation. For the NHANES databases, easy access to documentation is especially important. The precise definitions of variables, technical notes relating to characteristics of the data collection useful or necessary for data interpretation, counts of individual response categories, and guidance for use of the statistical weights necessary for correct calculations for variance and hypothesis testing, are all essential items to be made available with WebMIRS. Our approach is to provide this data as a hyperlink from the same Web site from which WebMIRS is available. Documents provided in electronic form by NCHS in ASCII form have been divided into logical sections, each with its own hyperlink. Sections have been kept to reasonable sizes to facilitate downloading of selected interest areas with minimal wait time. Options are provided to download entire documents for users who so desire, however; for example, the NHANES III Examination Data documentation (over 800 pages in printed form) may be downloaded in entirety. Keyword-searchability for all the documentation is provided by a search engine from the *Excite* company. An *Excite* search results in a list of hyperlinks to document sections, each of which contains the keyword. By selecting a section and using his/her browser search capability, the user may home in on specific occurrences of the keyword.

Quality of query and results interfaces. We address two issues here, one related to the use of Java as our system language, and the other related to user needs related to our particular (NHANES) databases.

- (1) Java and the user interface. Until recently our user interface was created with the Java Abstract Windowing Toolkit and with third party applet components. The Java AWT implements GUI components with a “peer-oriented” approach: on a Windows platform, it creates screen components by communicating with code written for producing Microsoft Windows components; on a Sun Solaris platform, it communicates with code written for producing Motif components. In the current AWT this has two shortcomings: first, screen appearance and control behavior may change somewhat across platforms; this can be highly significant if, for example, some of the screen controls disappear or appear only partially on the screen; second, screen appearance may also differ significantly across different display devices when the screen resolution differs or even across different screen resolutions on the same device. To minimize any effects of AWT peer-oriented screen problems, we are migrating our GUI components to components created by use of the Java Foundation Classes (JFC), which create components independently of code tailored for specific window managers (such as Windows or Motif). To obviate the problem of different screen appearance across various display devices, we intend to test the system on a range of devices with varying screen resolution and physical screen dimensions, with the low end being a 12.1” laptop display with 800 x 600 screen resolution. As a result of these tests we will iteratively modify our GUI code to provide the most consistent display across our target devices.
- (2) NHANES databases: user interface needs.

WebMIRS allows query by an essentially hierarchical approach on the user interface; that is, the data variable needed for a query may be contained within a category which is itself contained within higher-level categories, with only the top level of these categories begin initially exposed on the user interface. When specifying a search term at the top of the hierarchy, this is transparent to the user. For example, to search only on *age*, we may use a simple GUI interaction to specify *age > 50*. To get at the more complex data, however, the hierarchy becomes obvious. For example, to look for persons having moderate pain on flexing the cervical spine, we make choices from successive list boxes to specify *Physician’s Exam* (level 1 in the hierarchy), *Back* (level 2), *Pain on Flexion* (level 3), *Cervical-severity of pain* (level 4), and *Moderate* (level 5). The structure of this hierarchy is derived from the structure of the NCHS documentation and should be reasonably friendly to users familiar with this documentation. However, there are two drawbacks to this: first, the user may already know that the desired variable exists in the database, but has no way to directly specify it without descending this hierarchy. To address this problem, we are providing an additional search mechanism where each variable in the database will have a unique name, contained in the documentation; a list box on the GUI will allow direct selection of these names for search. Second, as noted above, the manner in which the search hierarchy appears on the user interface is derived from the NHANES documentation: a user who is familiar with the NHANES II documentation will know what categories of data are available under the top heading *Physician’s Exam*: examination data for the back, chest, heart, abdomen, kidney, etc. Other users, however, may not be familiar with the NCHS documentation and may prefer an alternative path to the items of interest, which exposes the available data items by grouping them in disease or body system categories or health interest areas. To address this second problem we will provide a data selection option by health component. The GUI will contain a list box showing the contents of the database organized by health component categories. Example NHANES III categories are cardiovascular disease, respiratory disease, diabetes mellitus, reproductive health, arthritis and related musculoskeletal conditions, and osteoporosis. This health component approach will also require the user to descend a hierarchy to arrive at the specific item desired, but this hierarchy is structured from health concepts, not from categories used in creating the NCHS documentation for the dissemination data sets.

A second user interface need is driven by the size of the NHANES records. If we consider one record to be all of the variables corresponding to one survey person, the size of the NHANES III records, for example, is about 4000 variables. In such a database it is neither feasible nor beneficial to the user to return all 4000 variables for each record which satisfies the user search criteria. Hence the GUI must provide a way to select from the total variable set those which are to be returned on a particular query. One design solution under consideration is to build a *query/return* mode into the system. *Query* or *return* mode will be selectable, with the modes being exclusive of each other. In *query* mode, database fields may be specified (e.g., *age*), along with value delimiters on the fields (e.g., *> 50*), and the results will be used to form a query. In *return* mode, the same user interface is used up to the point of identifying database fields, but in this mode, the GUI will not pop up any controls for specifying field

delimiters: the database field (e.g., age, race, sex) is simply marked to be returned for the records satisfying the query.

Capability to export results. It is essential that WebMIRS users have the capability to export query results in a form compatible with standard tools used to analyze the NHANES data. These tools include the SAS statistical analysis software and other software designed for analyzing data collected with the particular sampling methods used by NCHS, which requires the use of data weights (included in the NHANES data and available through WebMIRS) for correct variance estimation and for correct hypothesis testing. The ability to export these results is conceptually simple: just write ASCII files containing the data results, along with any additional control data needed by the particular software package being exported to. (This works nicely for software such as SAS that accepts data input in ASCII form.) The major difficulty in implementing this exporting is the restrictive nature of Java applet capability when executed by standard Web browsers. In order to preserve the security of a user's system from malicious attack across the network, applets are treated by the major Web browsers as *untrusted code* and are very restricted in what they can do on a user's machine. Specifically, untrusted code cannot create or write to local files, among a number of other restrictions, including restrictions on reading system environment parameters, printing, and contacting URL's on machines other than the one from which the applet was downloaded. With the latest releases of the Java Development Kit, as well as enhancements in Netscape Communicator and Microsoft Internet Explorer, it is now possible to have the user communicate to the browser that the applet is code that is trusted to have the necessary system privileges. Part of our current development effort is implementing the required capability to allow our WebMIRS applet to request local system access from the user, for the purpose of saving query results in the user's local file system.

Exploitation of multimedia data. The inclusion of image data within WebMIRS distinguishes our system from many other database implementations. One of our goals is to exploit this image data by providing within the database quantitative measures derived directly from the images. We are beginning this work by incorporating data from a selected set of 600 images into our database. Our general approach is to follow the image segmentation work as published by researchers in the field of vertebral morphometry⁶. For the cervical spine images, for example, these measures will include features for each of the vertebrae: anterior, posterior, and medial heights; spacing between the vertebrae, and size measurements for any *osteophytes* (bony growths at the vertebral corners) present at the top or bottom of the anterior vertebra. Some of these features have been associated with medical conditions: for example, the anterior/posterior height ratio has been associated with vertebral fracture (in the thoracic spine)⁷. Others, such as the disk space measurements and osteophyte size, are quantifications of features usually used by rheumatologists to evaluate x-rays for degree of osteoarthritis present. (Reference [8] provides a general overview of osteoarthritis, including features such as osteophytes associated with degenerative joint disease of the spine.) By making these measures available, we intend to eventually open this x-ray collection to exploitation by any biomedical researchers who are interested in correlating the quantitative measures with other information collected in the surveys. We describe our work in more detail in [9].

Thin client. Applet size is quite important for systems, which intend to serve a user community, which includes those having low-end bandwidth, typified by 33.3 kbps modem access. While delivery of images on a large scale to this user community is not feasible, we do intend to provide complete text access. With a large applet size, the user on the low bandwidth connection experiences a long startup time, waiting for the applet and any dependent classes to be downloaded. To minimize this problem, we are minimizing our applet size and limiting the applet class dependencies to classes likely to be already installed on the users' machines as part of their Web browsers, as far as this is possible. WebMIRS is a custom-written Java applet. It depends on Java classes from (1) the Java Foundation Classes and (2) third party Java applets. To the extent possible, we intend to replace the third party code with JFC class code. For browsers which support JFC (meaning that the JFC classes are automatically installed and available on the user's machine when the Web browser is installed) only our custom Java code and any non-removable third-party code will have to be downloaded. Unfortunately, at the current time, there is no common agreement between the major Web browser vendors on support for JFC, or for any other common set of foundation development classes for Java.

3. IMPLEMENTATION

WebMIRS supports databases built from NHANES II and NHANES III data; for NHANES II, digitized x-ray images are available as part of the query results. WebMIRS provides a graphical user interface (GUI) which allows the construction of SQL queries by interactions with buttons, list boxes, and data entry fields; feedback on the number of hits to a particular query; choices for numbers of records and types of images to download; and a results screen which presents both images and associated text in separate, scrollable screen regions. For the NHANES III database, only text is provided at the current time, but the system is designed with the capability to accept digitized NHANES III hand and knee images as they become

available. (They are being digitized at the current time.) WebMIRS provides a table format display option to facilitate data analysis; and allows user onscreen plotting of selected columns from the tabulated results.

WebMIRS uses the MySQL DBMS with a JDBC interface to manage its databases; we expect to transition from this DBMS to the Informix Universal Server. We have taken advantage of commercially-available Java components to reduce development time: the WebMIRS tabular data view is created with the Objective Grid package from *Stingray Software*, and the WebMIRS plotting capability is provided by the NetCharts package from NetFactory. Java JDK 1.0.2 was used as the basic tool for the initial Java development; we are now at the JDK 1.1.5 level. The driver necessary for the client to use JDBC is a JDBC Type 4 driver written in pure Java and downloaded dynamically from the server at the time the user starts the WebMIRS applet to avoid imposing any software requirement on the user, other than having a standard, Java-enabled Web browser. The text data retrieval is a transaction between the applet on the client machine and the database server, while the image retrieval is handled separately by the Web server; in the current WebMIRS, images are treated as files to which the database points, not as members of the database themselves.

Figure 1 shows the WebMIRS *Login* screen with a list box control to select the particular database to query. WebMIRS supports queries of the text records using standard SQL syntax that is automatically generated by the user's interactions with the GUI. It requires no a priori knowledge of field or table names in the database. An example WebMIRS SQL query, in English, is, *Find the records of all females older than 40 who had moderate pain on flexing the cervical spine*. Figure 2 shows this query to the NHANES II database created on the WebMIRS *Main Panel*. The tabs on this screen will provide access to the three query interfaces (only one query interface is provided now). The results of the query are shown in Figure 3, the *Database Information* screen. Images are presented at the top of the screen in a sliding window, while the text, which describes the current image (identified with a red border), is in a scrollable area at the bottom of the screen. The user may change the current image by clicking on any image within the sliding window at the top. This will cause the text to automatically update. If more than one type of image is associated with the records, the user may change the display to show other types, as shown in Figure 4, where the user has used the control in the upper left to select *lumbar spine* images for display, as opposed to *cervical spine* images. An alternative view of the query results is shown in Figure 5, the *Table View*. Here the results are presented in columns for the convenience of review by the analyst. Capability will also be added to the system to save query results and export them to standard statistical analysis packages. Two pie charts of columns in the Table View are shown; other plot types, including histograms and X-Y plots, will be added. Figure 6 illustrates access to the NHANES III documentation; in Figure 7, one of the NHANES III documents has been opened to show a partial list of topics covered in NHANES III. Figure 8 shows a query to the NHANES III database, *Find the records of all black females aged 41-49 having a cholesterol value greater than 250*. Table views of the query results are shown in Figures 9 and 10. In Figure 10, the Table View, a plot made from one column in the Table View, and access to NHANES III documentation are shown simultaneously on the screen.

The decision to use the Java programming language was made in order to take advantage of the capability this technology provides to build complex programs using object-oriented software methods, which may be downloaded to standard Web browsers in the form of Java applets. WebMIRS has been successfully demonstrated at the Radiological Sciences of North America (RSNA) annual meeting in Chicago (December 1996), at the Centers for Disease Control and Prevention (CDC) Data User's Conference in Washington, DC (July 1997), and at the annual meeting of the American College of Rheumatology (ACR) also in Washington, DC (November 1997). In each case, it allowed users to query and display results, including text and images, from NHANES databases at NLM in Bethesda, Maryland.

4. SUMMARY

The WebMIRS system will provide Web access to two important national health survey databases. The data will include not only textual information, but digitized x-ray images as well. Expected users are epidemiologists, rheumatologists, and medical educators. We have created a prototype system for two small databases created from NHANES data and are currently extending our work by enlarging the scope of our databases, providing capability to query using alternative GUI features, select data for downloading, and export results to local file systems. Comprehensive, keyword-searchable documentation for the two databases is being put on our Web site. We are also incorporating into the system quantitative feature information derived directly from the images. These features, such as anterior, posterior, and medial heights, disc space measurements, and osteophyte sizes, will be searchable independently or in conjunction with the health survey text.

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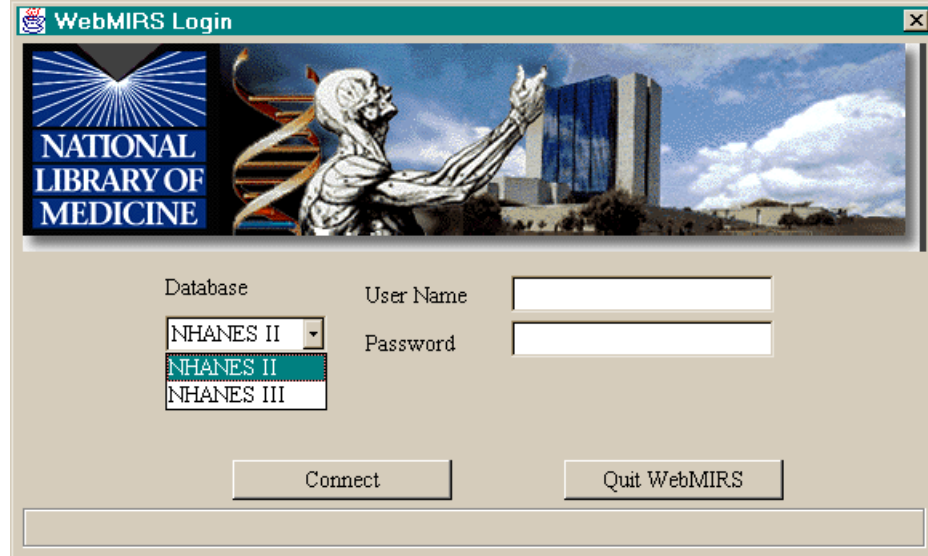


Figure 1. WebMIRS Login screen. Either the NHANES II or NHANES III database may be selected for query.

WebMIRS Main Panel

Current Database - NHANES II

Default Search: Search by Index Search by Category

DEMOGRAPHIC FEATURES

Age	Sex
	Female
Race	
Ethnicity	
Region	
Weight	
Height	

EXAMINATION FEATURES

Topic	Topic	Feature	Value
Physician's Exam	Pain	Neck - Severity of Pain	Moderate
		Other	None
		Low Back	Chronic
		Throat	Moderate
		Uncertain	Moderate
			Black Dot Applicable

Select relations below and press AND or OR to form a query

Age = 50
Sex = Female
Subtopic = Pain on Flexion and Feature = Cervical - Severity of Pain

AND --> OR -->

Constructed Query

Age = 50
AND
Sex = Female
AND
Subtopic = Pain on Flexion and Feature = Cervical - Severity of Pain and V

Select All Delete

Submit Query New Database Quit WebMIRS

Figure 2. WebMIRS Main Panel showing NHANES II database query, *Find records for all women older than 40 who had moderate pain on flexing the cervical spine.* The tabs will provide three different search interfaces.

WebMIRS Database Information

Cervical

Find Record

RECORD POSITION

Cur. Record = 1

Max. Records = 20

Previous Rec. = 20

Current Rec. = 1

Next Rec. = 2



DEMOGRAPHIC DATA

Sample No. = 6706

Age = 50

Sex = Female

Race = WHITE

ETHNICITY = STAY European

Region = SOUTH

Weight (kg) = 66.67

Height (cm) = 158.8

View First Set Search Again View Query Quit WebMIRS

Figure 3. WebMIRS Database Information screen, showing results of Figure 2 query. The text describes the person with image highlighted with a red border. The image area may be scrolled horizontally; the text may be scrolled vertically.

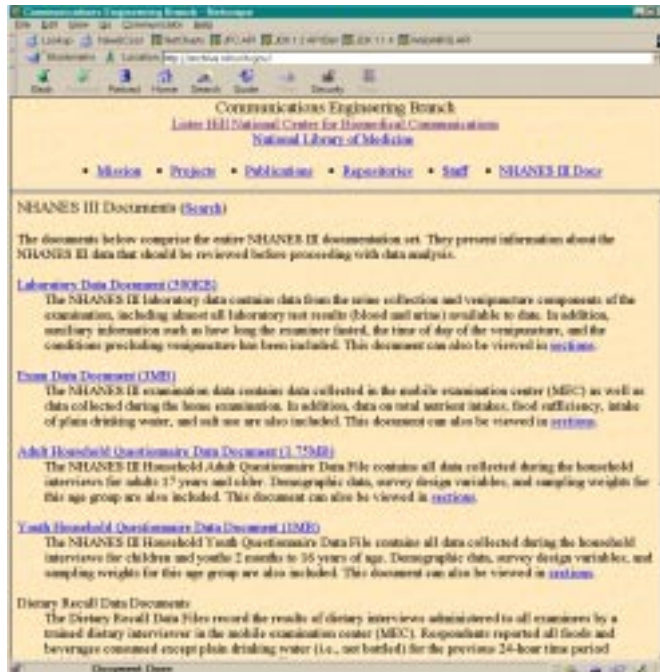


Figure 6. NHANES III documentation may be accessed on the NLM Communications Engineering Branch web page (<http://archive.nlm.nih.gov>). Complete documents or sections may be downloaded; keyword-search is provided.

Topic	HA	HT	EXAM	LAB	DIET
Alcohol and drug use	1	+	+	1	+
Reproductive health	1	+	+	1	+
Diagnostic interview schedule	1	+	+	1	+
Activity	1	+	+	1	+
Physician's examination	1	+	+	1	+
Height and weight	1	+	+	1	+
Body measurements	1	+	+	1	+
Dental examination	1	+	+	1	+
Allergy skin test	1	+	+	1	+
Audiometry	1	+	+	1	+
Tympanometry	1	+	+	1	+
WISC and WWAT	1	+	+	1	+
Pneumometry	1	+	+	1	+
Bone densitometry	1	+	+	1	+
Salivary gland ultrasonography	1	+	+	1	+
Central nervous system function evaluation	1	+	+	1	+

Figure 7. A view into the NHANES III Examination Data File documentation, showing some of the topics covered in NHANES III and which NHANES III files contain that topic.

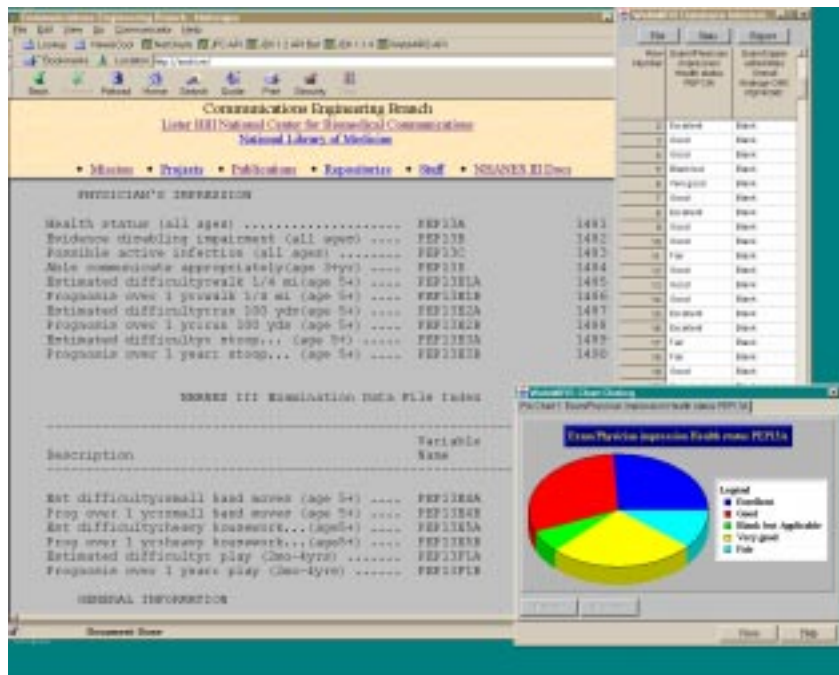


Figure 10. Here the Table View of the results in Figure 9 has been resized (upper right) and the variable *Health status* has been charted. In the background, the NHANES III documentation has been accessed to display a *Health status* reference.